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Causal sustainable resource management model using a hierarchical structure and linguistic preferences

Kuo-Jui Wu [a], Ming Lang Tseng [b, c, *], Ming K. Lim [d], Anthony SF. Chiu [e]

[a] School of Business, Dalian University of Technology, Panjin, 124221, China
[b] Institute for Innovation and Circular Economy, Asia University, Taichung, Taiwan
[c] Department of Medical Research, China Medical University Hospital, Taiwan
[d] College of Mechanical Engineering, Chongqing University, China
[e] Department of Industrial Engineering, De La Salle University, Manila, Philippines

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ABSTRACT

Issues associated with resource exhaustion and climate change continue to worsen, and sustainable resource management is considered a method of resolving these problems. However, academia and industry have primarily focused on managing sustainable production and consumption and neglected resource management model. In addition, an appropriate tool must be developed for evaluating sustainable resource management model that considers the interrelationships and provides a guideline for performance improvement. This study proposes the application of an exploratory factor analysis to filter potential measures and the generation of a hybrid fuzzy synthetic method and decision-making and trial evaluation laboratory to assess the performance via a visual attribute map. The results demonstrate that social resources must prioritize and interact with environmental resources and indicate that economic resources are interrelated with social and environmental resources. Hence, this study enhances the understanding of causal sustainable resource management model by proposing a hybrid method for assessing performance via a hierarchical structure and offering a guideline to assist in performance improvements.

1. Introduction

As natural resources become exhausted and climate change worsens, academia and industry are striving to identify an optimal method of managing resources to achieve sustainability. Several regulations have been passed to reduce environmental impacts, such as the regulations passed by the United States in 1992; subsequently, the European Union enacted waste, electrical and electronic equipment (WEEE) and energy-using product (EuP) directives in 2005, the Restriction of the Use of Hazardous Substances (RoHS) in electrical and electronic products in 2006 and Registration, Evaluation, Authorization and Restriction of Chemicals (REACH) in 2007. Although these directives and regulations have prevented damage to the ecosystem, the Taiwanese electronics industry has encountered difficulty in finding substitute materials and adopting eco-designs that comply with these regulations. This difficulty has resulted in an increased industry focus on managing economic and environmental resources and a lack of focus on social resources. Thus, several well-known Taiwanese electronic firms merged and were acquired by well-known international firms. The observed phenomena demonstrate the urgent need to assist the industrial sector in diagnosing the problems associated with attaining sustainable resource management (SRM) (Tseng et al., 2018a; b; Wu et al., 2018). In addition, an appropriate evaluation tool is not available to diagnose the problems associated with avoiding wasted resources while performing improvement.

In the literature, Pahl-Wostl (2007) reported that SRM should concern itself with social feedback within this complex and uncertain world. Carter and Rogers (2008) simultaneously extended the concept using economic, environmental and social considerations. Lin et al. (2016) implied that firms' economic resources needed to be focused on performance measures aimed at sustainable development. Bringezu and Bleischwitz (2017) defined SRM as follows: "*each economic system rests upon utilizing the natural*

* Corresponding author. Institute for Innovation and Circular Economy, Asia University, 500, Lioufeng Rd., Taichung, 41354, Taiwan.

E-mail addresses: wukuojui@dlut.edu.cn (K.-J. Wu), Tsengminglang@asia.edu.tw (M.L. Tseng), ming.lim@cqu.edu.cn (M.K. Lim), anthony.chiu@dlsu.edu.ph (A.SF. Chiu).

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resources in rational ways and maximizing human well-being without impeding the supporting *of the living eco-system*." Dong et al. (2018) presented an innovative system for exploring the key points to attaining SRM, including innovative governance and management, holistic and integrated assessment tools, more efficient and environmentally friendly technologies/facilities and decision support tool and indicators. These studies applied diversity points to discuss methods of attaining SRM. Nevertheless, these prior studies lacked guidelines and appropriate assessment measures and tools to address SRM for performance improvement.

Prior studies used quantitative data or case studies to analyze the lack of interrelationships among the attributes, and several studies even explained how to screen for valid and reliable attributes (Sanginga et al., 2003; Prior et al., 2012; Damastuti and de Groot, 2017). However, SRM possesses multiple attributes and includes several qualitative perspectives, which must be considered to reflect the real situation and identify the specific attributes required to improve performance with limited resources. Thus, this study integrates an exploratory factor analysis and the fuzzy synthetic method (FSM) with a decision-making and trial evaluation laboratory (DEMATEL) to address these gaps. The exploratory factor analysis is used to screen for valid and reliable attributes, the FSM is used to solve non-deterministic problems and transform human opinions into quantitative analysis of linguistic preferences, and the DEMATEL is used to assist decision makers in identifying decisive attributes via a visual analysis by categorizing the attributes into cause and effect groups.

Therefore, the objectives of this study are to assess SRM performance and explore the effective attributes and core problems associated with improving performance toward sustainability. This study provides three contributions in this context: (1) the collected criteria and perspectives enable us to provide a theoretical basis for enhancing our understanding of SRM via significant evidence; (2) the proposed FSM-DEMATEL improves on the shortcomings of traditional fuzzy set theory and the DEMATEL method with hierarchical structures; and (3) the analytical results indicate the attributes and core problems needed to guide industry towards improving performance under resource constraints.

This study is organized as follows. The theoretical background, proposed methods and measures are presented in section 2. The FSM-DEMATEL method and the proposed analytical procedures are described in section 4. The case information and analytical results are discussed in section 4. The theoretical and managerial implications are presented in section 5. The conclusions, study limitations and possible future studies are listed in the final section.

2. Literature review

This section provides a review of studies focused on SRM. The review indicated that few prior studies have been conducted on the proposed method. Finally, the proposed measures are presented.

2.1. Sustainable resource management

SRM has been widely discussed when analyzing efficient and effective methods of managing resources with a focus on sustainability. However, Lawton and Weaver (2010) presented the advantages of practicing SRM, which increase the opportunities to improve quality with lower execution costs and obtain higher returns both in cost savings and positive advertising associated with the locations. Prior et al. (2012) addressed resource exhaustion and proposed managing resources as a service provider concept. In this study, resource exhaustion is not considered a disaster but a trigger for considering methods of managing/using resources more efficiently. Voulvoulis et al. (2013) attempted to explore the closed-loop process of managing mining resources, from raw materials, goods and services, consumption, disposal, restoration/regeneration, resources and back to raw materials. Coppens et al. (2016) published an extensive discussion that considered air, industry, consumption, agriculture, waste management, soil and water to explore the high-resolution nutrient flows throughout the economy toward SRM. These studies proposed enhancing SRM and concentrated on economic and environmental resources only.

Several studies have argued that the public is not involved in business management and should not bear SRM responsibility (Sanginga et al., 2003; AmerAlgotsson, 2006). SRM requires specific boundaries and an enhanced understanding of the parameters that can increase awareness and transform current resource governance and management systems via social resources (Bouwen and Taillieu, 2004; Pahl-Wostl, 2007; Pahl-Wostl et al., 2013). SRM might lead to increased productivity through the gathering of available local renewable and residual social resources (Leduc and Van Kann, 2013). Damastuti and de Groot (2017) studied social resources, including community governance and livelihood, as criteria for assessments and then associated these resources with four Indonesian villages to compare their ability to attain SRM. Moreover, Guo et al. (2017) adopted an input-output model that considers a production system for human society, stock composition and eco-systems to formulate a lifecycle framework. These prior studies attempted to expand the discussion from economic and environmental resources to social resources because the latter might generate unanticipated impacts, either positive or negative, on firms.

Several normative SRM industrial practices have been launched, such as reusing containers, recycling paper packages, preventing harmful material utilization and disposal, reducing waste, promoting energy and water efficiency, improving air quality, considering reverse logistics, remanufacturing components, etc., and all these practices have previously been implemented (Zurburg et al., 1995; Lawton and Weaver, 2010; Cui et al., 2017). Emphasized improving evaluation tools to promote a greater understanding of resource and environmental efficiency; moreover, the evaluation tool allows stakeholders to adjust resource management policies instantaneously to align the strategies and social expectations in the business field. Hence, this study proposes a hybrid method to assist industry in assessing performance to provide guidance for further improvement.

2.2. Proposed analytical methods

Previous studies have primarily used quantitative data to formulate models that have single perspectives on the exploration of optimal SRM. For example, Kotir et al. (2017) utilized system dynamics to discuss water use issues and generated three scenarios toward SRM in the Western African savannah zone. However, qualitative information was not included in the discussion and analysis. Knüppe and Meissner (2016) used qualitative interviews with 18 experts to attain useful information for identifying the drivers and barriers toward SRM. Pires et al. (2017) chose 170 indicators from a literature review, asked experts to evaluate the performance of these indicators and applied the fundamentals of descriptive statistics. Later, Chen et al. (2017) combined waste-stream modeling with a material flow analysis as a decision-making tool to attain optimal solutions. Guo et al. (2017) applied a lifecycle impact assessment and material metabolism to explore SRM in China. Dong et al. (2018) emphasized that evaluation approaches, decision support tools and database construction are key points for exploring SRM. Moreover, valid and reliable hierarchical structures must be developed. Hence, exploratory factor analyses

group the hierarchical attributes and assume that the attributes are interrelated.

Although the aforementioned studies provided optimal solutions for addressing the issue of SRM, hierarchical structures were not considered in the analytical process. In addition, each criterion and perspective are assumed to be independent, and qualitative information still utilizes basic descriptive statistics, which inappropriately represent the actual problem and linguistic preferences. To overcome these shortcomings, this study proposes integrating the FSM with the DEMATEL to assess the performance of SRM. The FSM is used to transform qualitative evaluations into quantitative analyses, and it has been broadly applied in risk assessments of green buildings and public-private and industrial partnerships (Zhao et al., 2016; Wu et al., 2017). Haider et al. (2018) developed a hierarchical framework associated with the FSM to provide analytical results for socio-economic sustainability assessments. Li and Jin (2018) used an early-warning system based on a hybrid between an optimization algorithm and the FSM to evaluate environmental impacts.

The DEMATEL provides a visual analysis for simplifying complex problems into a two-dimensional diagram (Wu et al., 2015). The assessed criteria and perspectives can be mapped onto a diagram under four quadrants; therefore, the decision-maker needs to focus on only the driving factors and core problem in quadrants, which provide guidelines that lead to improvements. Gölcüka and Baykasoglu (2016) hybridized the DEMATEL and analytical network processes to consider the interrelations among criteria and developed a network framework via a comprehensive literature review of these two methods. Lin et al. (2017) improved the life span of the traditional DEMATEL to analyze product innovation. Lin et al. (2017) used approximate fuzzy DEMATEL to evaluate sustainable supply chain management under an uncertain environment. Thus, controlling for the utilization of resources at a sustainable level can provide an opportunity to achieve SRM if the evaluation tools associated with human beings are developed (Bringezu and Bleischwitz, 2017). Prior studies have emphasized the essential need to develop an appropriate tool for evaluating and acquiring SRM.

2.3. Proposed SRM measures

The social resources perspective consists of the organization's relationships with its many and various stakeholders (Andersson, 2018). According to this concept, multi-stakeholder engagement (C1) relates to various stakeholder groups via shared values and through connecting with strategic processes to acquire common resources (Lozano, 2012; Tseng et al., 2018). Human capital development (C2) can enhance awareness via investments in education and health to generate positive resources (Steger, 2002; Bonn and Fisher, 2011). Diversity evaluations (C3) can maintain common differences, which are considered buffers when resources are exhausted. Aligning efforts and agreements (C4) fulfills the expectations of the public to generate more positive feedback for reinforcing social resources. In addition, human resource management (C5) is considered a powerful tool for regenerating resources as observed in Japanese businesses, and it can be used to acquire internal support and generate changes that reflect the organizational structure (Loorbach and Rotmans, 2010). Synergistic organization (C6) can be used to acquire social resources by engaging stakeholders with an aligning industrial strategy and maintaining investor relationships by considering the long-term interactions between industry and individuals within the capital market (Tseng et al., 2018). Reputation (C7) represents the image of an organization, and it is based on the initial impression formed when the industry is considered (Tseng, 2017). Once the industry has established a positive reputation, it can shift resources towards generating benefits. Increasing employee and customer awareness (C8) can promote the efficiency of resource utilization through education and advertisements and the acquisition of positive social resources (Shi et al., 2017).

The environmental resource perspective involves all types of natural resources without harming human life-supporting eco-systems. Thus, eco-innovation (C9) plays an important role in generating environmental resources, and it includes eco-organization, eco-purchasing, eco-production and eco-product and service design (C14) (Wu et al., 2015; Wu et al., 2016a; Tseng, 2017). To control environmental resources, lifecycle management (C10) is a useful instrument that offers strategic linkages with business solutions to support the creation of management advertising and utilize product information throughout the entire product lifecycle (Wu et al., 2016b; Clermont and Kamsu-Foguem, 2018). In addition, supporting living eco-systems (C11) is considered an important task for acquiring benefits and guaranteeing resources without generating negative impacts on the environment. Developing cleaner technology (C12) facilitates an organization's ability to obtain and utilize natural resources more efficiently, produce/offer products and services with less harmful impacts, and minimize pollutant emissions within the manufacturing and production utilization cycles (OECD, 1995; BüYüKöZkan & ÇIfçI, 2013). Thus, environmental management systems (C13) relate to managing an organization's environmental program via extensive, systematic types of planning and documenting to attain sustainable resource utilization goals. Furthermore, many firms are pursuing component recycling (C15) to attain SRM with normative regulations listed in WEEE directives. If 95% of the components obtained by industrial organizations can be recycled and reused, then the issue of resource exhaustion may be mitigated.

The economic resources perspective is a broad perspective related to the generation of profits or benefits to support system operations. Quality improvement (C16) allows industrial organizations to attract customers and provide greater satisfaction, and this satisfaction can generate profits by the public disclosure of market shares or revenues (Lim et al., 2017; Wang et al., 2018). A material flow system (C17) requires the knowledge and expertise to address complex resource optimization (Chen et al., 2017). The benefits from sustainable design (C18) refer to establishing awareness of the connection between innovation and sustainability to embrace sustainable design and product stewardship (Küçüksayraç, 2015; Rahdari and Rostamy, 2015; Tseng, 2017). In addition, supply chain finance (C19) can improve the performance of economic resources by offering longer payment terms for buyers and better access to funding for suppliers (Wuttke et al., 2016). If an industry organization can promote the forecast accuracy (C20) for demand, then the reduced waste and inventory can provide flexibility and visibility for the control of economic resources (BüYüKöZkan & ÇIfçI, 2013; Wu et al., 2016b). Subsequently, optimal capability utilization (C21) provides greater efficiency in managing production and lead time, and better utilization can generate greater economic resources (Lin and Tseng, 2016). Collaboration and coordination in supply chain networks (C22) require cohesion among all members along the supply chain via the sharing of information/data, establishment of pricing strategies, performance of group purchasing and so on (Zhou et al., 2017; Zhang and Wang, 2018). Once collaboration and coordination is established among supply chain members, economic resources can be captured via the professional application of their coherent roles.

3. Methods

This section provides mathematical equations for enhancing our

understanding of how the FSE-DEMATEL can be implemented to evaluate the proposed criteria and perspectives. The last subsection provides a detailed description of the proposed analytical procedures for promoting the applications.

3.1. Exploratory factor analysis

Exploratory factor analyses are used to reveal the underlying structure of a relatively large set of https://en.wikipedia.org/wiki/Variable_(research)attributes. The overarching goal is to identify the underlying interrelationships between measures and the set of aspects shared by these measures. Exploratory factor analysis procedures are more accurate when each aspect is represented in the analysis by multiple measured criteria to process the reliable and valid measures (Amerioun et al., 2018; Ruscio and Roche, 2012).

3.2. Application of FSM-DEMATEL to criteria

The fuzzy synthetic method is a branch of fuzzy set theory that can be used for solving various types of problems with nondeterministic features. This method enables the transfer of linguistic scales into quantitative calculations by adopting the membership grade theory and providing appropriate results (Shidpour et al., 2016; Wu et al., 2017). In this study, assuming that the method has α sets of criteria under β perspectives by γ experts, the evaluation can be expressed as follows: $[\varepsilon_{ij}]^{\beta}_{\alpha\gamma}$. The parameter e_{ij} is adopted for linguistic preferences to represent the evaluation results, which include very low (*VL*), low (*L*), medium (*M*), high (*H*) and very high (*VH*) scales. Based on the frequency of these scales, the equation is rewritten as follows:

$$[\varepsilon_{ij}]^{\beta}_{\alpha\gamma} = [a_{ij}, b_{ij}, c_{ij}, d_{ij}, e_{ij}]^{\beta}_{\alpha\gamma} \tag{1}$$

where $a_{ij}, b_{ij}, c_{ij}, d_{ij},$ *and* e_{ij} represent the accumulated frequencies of *VL* (1), *L* (2), *M* (3), *H* (4) and *VH* (5), respectively.

Subsequently, these accumulated frequencies must be converted into weights via the following equations:

$$\left[\frac{a_i}{\tau}, \frac{b_i}{\tau}, \frac{c_i}{\tau}, \frac{d_i}{\tau}, \frac{e_i}{\tau}\right]^{\beta}_{\alpha} \tag{2}$$

where $\tau = a_i + b_i + c_i + d_i + e_i$.

These weights are input into the following equation to generate crisp criteria v_i values for further calculations:

$$[v_i]^{\beta}_{\alpha} = [1 \times a_i + 2 \times b_i + 3 \times c_i + 4 \times d_i + 5 \times e_i]^{\beta}_{\alpha} \tag{3}$$

Accordingly, these values can be rearranged into the self-matrix *V* based on the number of β perspective as follows:

$$[V]^{\beta}_{\alpha\times\alpha} = [v_{ij}]^{\beta}_{\alpha\times\alpha} \tag{4}$$

Then, the arithmetic mean is applied to aggregate these self-matrices into the direct relation matrix *T* via the following equation:

$$T = \frac{\sum_{i=1}^{\beta} v_{ij}}{\beta} = [t_{ij}]_{\alpha\times\alpha}, j = 1, 2, 3, \cdots \beta \tag{5}$$

Once we attain the direct relation matrix, the following equation can be used to normalize the direct relation matrix:

$$R = \frac{t_{ij}}{\max\limits_{1\le i\le\alpha} \sum_{i=1}^{\alpha} t_i} \tag{6}$$

Using the normalized direct relation matrix, the total relation matrix is obtained with the following equation:

$$S = R \times (\tau - R)^{-1} \tag{7}$$

where τ represents the identity matrix and *S* can be rewritten as $[s_{ij}]_{\alpha\times\alpha}$.

Based on the total relation matrix, the following equations are used to generate the driving power (*dr*) and dependence power (*dp*).

$$dr = \left[\sum_{i=1}^{\alpha} s_{ij}\right]_{\alpha\times 1} = [s_i]_{\alpha\times 1} \tag{8}$$

$$dp = \left[\sum_{j=1}^{\alpha} s_{ij}\right]_{1\times\alpha} = [s_j]_{1\times\alpha} \tag{9}$$

The terms ($dr + dp$ *and* $dr - dp$) can be used to arrange the cause and effect diagram of the criteria, where $dr + dp$ represents the importance of the criteria along the horizontal axis and $dr - dp$ is used to group criteria into cause and effect groups along the vertical axis. If $dr - dp > 0$, the criteria are considered a cause group; otherwise, the criteria are allocated to the effect group.

3.3. Using FSM-DEMATEL for perspectives

Then, by adopting the geometric mean, the measurement criticality M^{β} of the criteria under each perspective is calculated to realize how the criteria are related to the perspective via the following equation:

$$M^{\beta}_{\alpha} = \left[\sqrt[\alpha]{\prod [v_i]_{\alpha}}\right]^{\beta} = [m_i]^{\beta}_{\alpha} \tag{10}$$

This measurement criticality must be transformed into a factor weight, which is combined with the criteria evaluations into perspectives as follows:

$$[F]^{\beta}_{pq} = \frac{m_i}{\sum_{i=1}^{q} m_i} = [f_{xy}]^{\beta}_{pq}, \; q = 1, 2, 3, \cdots n \tag{11}$$

where *q* represents the category based on Table 1.

To aggregate the all frequencies into perspectives, the following equation is used to attain the average frequencies based on the perspective considerations.

$$[\tilde{\varepsilon}]^{\beta}_{qr} = \left[\sqrt[\alpha]{\prod_{i=1}^{\alpha} a_{ij}}, \sqrt[\alpha]{\prod_{i=1}^{\alpha} b_{ij}}, \sqrt[\alpha]{\prod_{i=1}^{\alpha} c_{ij}}, \sqrt[\alpha]{\prod_{i=1}^{\alpha} d_{ij}}, \sqrt[\alpha]{\prod_{i=1}^{\alpha} e_{ij}}\right]^{\beta}_{qr} = [\tilde{\varepsilon}_{ij}]^{\beta}_{qr} \tag{12}$$

Table 1
Proposed criteria and perspectives.

2. Table 2 presents the responses of the 55 experts, and the evaluations were adapted to five-point linguistic scales. However, these scales must be transformed into crisp values for further use by applying Eqs. (1)–(3) as presented in Table 3. Thus, the crisp value of C1 is calculated as $1\times 0.1563+2\times 0.3125+3\times 0.1563+4\times 0.1875+5\times 0.1875=2.9375$.
3. Eq. (4) can be used to arrange the criteria into a self-matrix as shown in Table 4. The direct relation matrix for the three criteria of the self-matrices are developed using Eq. (5). For example, the self-matrix criteria under A1, A2 and A3 are 2.9375, 3.2188 and 3.3750, respectively; therefore, the first number in Table 5 (marked in gray) is $\frac{\sum_{i=1}^{\beta}v_{ij}}{\beta}=\frac{(2.9375+3.2188+3.3750)}{3}=3.1771$. Table 6 presents the total relation matrix with the *dr* and *dp* generated using Eqs. (6)–(9).

Perspectives		Criteria		Factor loading
A1	Social Resources (Cronbach's alpha 0.871; CR = 0.873; AVE = 0.825)	C1	Multi-stakeholder engagement	0.923
		C2	Human capital development	0.907
		C3	Exploration of diversity	0.893
		C4	Aligning efforts and agreements	0.876
		C5	Human resources management	0.852
		C6	Synergistic organization	0.793
		C7	Reputation	0.785
		C8	Employee and customer awareness	0.778
A2	Environmental Resources (Cronbach's alpha 0.862; CR = 0.859; AVE = 0.818)	C9	Eco-innovation	0.889
		C10	Lifecycle management	0.856
		C11	Supporting living eco-systems	0.842
		C12	Developing cleaner technology	0.801
		C13	Environmental management systems	0.793
		C14	Eco-product and service design	0.784
		C15	Component recycling	0.776
A3	Economic Resources (Cronbach's alpha 0.795; CR = 0.787; AVE = 0.788)	C16	Quality improvement	0.876
		C17	Material flow system	0.864
		C18	Benefits from sustainable design	0.833
		C19	Supply chain finance	0.821
		C20	Forecast accuracy	0.808
		C21	Capacity utilization	0.777
		C22	Collaboration and coordination in supply chain networks	0.725

Table 2
Evaluations of 55 experts under criterion 1.

	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13	E14	E15	E16	E17	E18	E19	E20	………	E51	E52	E53	E54	E55
C1	VH	H	L	M	L	H	M	VL	VL	VH	H	VL	M	L	VL	L	VH	L	L	M	………	L	H	H	VH	L
C2	H	H	VH	VL	VH	L	VH	L	M	M	M	VH	VH	VL	L	H	VH	H	VL	L	………	M	H	VH	L	VH
C3	VH	H	VL	H	VL	M	H	VH	L	L	VH	H	M	VH	H	L	VL	VL	VH	L	………	VL	L	L	L	VH
C4	H	VH	M	M	L	VH	H	L	M	M	VL	VH	L	L	VH	VL	H	H	VL	VH	………	VL	M	VH	H	M
C5	VH	M	M	H	H	L	VH	L	M	M	H	VL	L	L	M	M	VL	H	L	M	………	VH	VH	VL	H	L
C6	VL	M	VL	H	M	M	H	VL	VL	VH	M	M	VH	VH	L	L	H	L	VH	M	………	VL	L	VL	M	L
C7	L	VL	M	VH	H	VH	L	VL	L	H	VL	VL	L	L	H	L	H	L	H	VL	………	H	M	H	VH	M
C8	VL	VH	VH	M	M	VL	M	L	M	VL	L	M	L	L	VH	VH	H	VH	VL	VH	………	H	L	L	H	VL
C9	L	VH	VL	H	M	H	VH	L	VH	H	L	VH	L	VH	L	M	M	M	VL	M	………	VH	VH	H	M	VH
C10	VL	L	M	H	M	M	L	VL	VH	M	M	M	L	M	M	M	VH	L	M	VL	………	L	H	H	VH	H
C11	H	VH	L	VH	H	L	M	VH	VH	H	VH	VH	L	VH	M	H	M	H	H	H	………	M	VL	VH	VH	H
C12	L	L	M	VL	M	VL	VH	L	VH	VH	M	VH	M	M	VL	VH	VH	VH	VH	VH	………	M	VH	M	L	VL
C13	VH	M	H	M	L	VH	VL	H	M	L	H	VH	M	H	M	VH	H	VH	VH	H	………	H	L	H	VH	H
C14	M	VL	VH	VH	M	M	L	M	L	M	VL	VH	M	VH	M	VH	H	VH	VL	L	………	L	M	VH	VL	VL
C15	L	M	M	VH	H	L	H	L	M	VH	VH	L	H	L	VH	H	VL	H	VL	H	………	H	VH	VL	M	H
C16	VL	H	VH	VL	M	VH	VH	M	VH	L	VH	L	H	VH	H	L	VH	VH	H	VL	………	H	H	H	L	VH
C17	L	H	VL	VL	L	L	M	L	VL	L	M	VH	M	L	L	L	VH	VL	VH	L	………	L	M	M	VH	VL
C18	L	VL	H	VH	M	VL	VH	M	L	VH	L	H	L	L	VH	M	VH	M	H	VH	………	VL	VH	M	VH	VL
C19	H	M	M	VH	VH	VL	L	VH	L	VL	H	VH	H	H	VH	VL	M	H	H	M	………	VH	L	M	M	L
C20	M	VH	H	VH	VH	M	VH	H	VL	VH	H	M	VH	VH	VH	H	VL	VH	L	M	………	VL	VH	VL	VH	L
C21	VH	VH	VH	VL	H	L	VL	VH	VL	M	H	VL	VH	VL	L	M	VH	VH	H	M	………	H	M	VH	H	VH
C22	H	VH	H	M	VH	M	L	M	M	VH	H	L	M	L	L	L	VL	M	H	H	………	VH	VH	M	L	M

These aggregating frequencies must be associated with factor weights to attain the membership function U^{β} of the perspectives via the following equation:

$$U_{pr}^{\beta}=[F]_{pq}^{\beta}\times[\tilde{\varepsilon}]_{qr}^{\beta}=\left[f_{xy}\tilde{\varepsilon}_{ij}\right]_{pr}^{\beta}=\left[u_{gh}\right]_{pr}^{\beta} \tag{13}$$

where $[u_{gh}]_{pr}^{\beta}$ can be denoted by $[u_{gh}^{1\beta},u_{gh}^{2\beta},u_{gh}^{3\beta},u_{gh}^{4\beta},u_{gh}^{5\beta}]_{pr}$.

These membership functions must be shifted to crisp perspective values to attain the direct relation matrix using the following equations:

$$A=\left[1\times u_{gh}^{1\beta}+2\times u_{gh}^{2\beta}+3\times u_{gh}^{3\beta}+4\times u_{gh}^{4\beta}+5\times u_{gh}^{5\beta}\right]_{pr}=[\tilde{a}_{ol}]_{\beta\times\beta} \tag{14}$$

The following equations are used to generate the total relation matrix:

Table 3
Crisp values under criterion 1.

	1	2	3	4	5	Crisp Value
C1	0.1563	0.3125	0.1563	0.1875	0.1875	2.9375
C2	0.1563	0.2188	0.1250	0.1875	0.3125	3.2813
C3	0.2188	0.2188	0.0625	0.2188	0.2813	3.1250
C4	0.1563	0.1563	0.2500	0.1875	0.2500	3.2188
C5	0.1563	0.2188	0.2500	0.1875	0.1875	3.0313
C6	0.2500	0.1875	0.2813	0.1563	0.1250	2.7188
C7	0.1875	0.2500	0.0938	0.2813	0.1875	3.0313
C8	0.1875	0.2500	0.1875	0.1563	0.2188	2.9688
C9	0.1250	0.1875	0.2813	0.1563	0.2500	3.2188
C10	0.1250	0.2188	0.3125	0.1875	0.1563	3.0313
C11	0.0938	0.1250	0.1250	0.2813	0.3750	3.7188
C12	0.1563	0.2500	0.2500	0.0313	0.3125	3.0938
C13	0.0625	0.1250	0.1875	0.3438	0.2813	3.6563
C14	0.1875	0.2813	0.2813	0.0313	0.2188	2.8125
C15	0.1250	0.2188	0.1250	0.2500	0.2813	3.3438
C16	0.1250	0.1875	0.1563	0.2500	0.2813	3.3750
C17	0.2188	0.3750	0.1563	0.0938	0.1563	2.5938
C18	0.1250	0.1563	0.2500	0.0938	0.3750	3.4375
C19	0.1250	0.1250	0.2500	0.2500	0.2500	3.3750
C20	0.2188	0.0625	0.1875	0.1563	0.3750	3.4063
C21	0.2188	0.1250	0.1563	0.1875	0.3125	3.2500
C22	0.0625	0.1875	0.3125	0.2188	0.2188	3.3438

$$\tilde{R} = \frac{\tilde{a}_{ol}}{\max\limits_{1\le o\le \beta}\sum_{o=1}^{\beta}\tilde{a}_o} \tag{15}$$

$$\tilde{S} = \tilde{R} \times \left(\tau - \tilde{R}\right)^{-1} = [\tilde{s}_{ol}]_{\beta\times\beta} \tag{16}$$

The effects among perspectives are calculated using the following equations:

$$\vartheta = \frac{\sum_{o=1}^{\beta}\tilde{s}_{ol}}{\beta^2}, l = 1, 2, 3, \cdots \beta \tag{17}$$

If $\tilde{s}_{ol} > \vartheta$, then the perspective has an effect on two aspects, and the effect is $\tilde{s}_{ol}$. Otherwise, it does not have an affect on $\tilde{s}_{ol}$, where ϑ is the threshold for screening the effects between two perspectives.

3.4. Proposed analytical procedures

1. The criteria generated for SRM are evaluated by 55 industrial experts and academicians. These criteria are filteredby performing a literature analysis and exploratory factor analysis. Once the collected criteria are finalized, the experts are asked to evaluate these criteria based on their personal expertise and experiences. The selected experts have at least five years of working experience in the related industry.
2. The evaluations are provided on a linguistic scale, and Eq. (1) is used to converted the results into quantitative values for further calculations. Then, Eqs. (2)–(4) are used to generate crisp values for the criteria. These values are then aggregated into a direct relation matrix using Eq. (5).
3. Eqs. (6) and (7) are applied to calculate the total relation matrix after the direct relation matrix is obtained. Eqs. (8) and (9) can be used to generate the *dr* and *dp*. Based on the *dr* and *dp*, the criteria are then arranged into a cause and effect diagram for a visual analysis.
4. Adopting Eqs. (10)-(13) shifts the evaluation of the criteria into membership functions of perspective. These membership functions are input to Eq. (14) to acquire the crisp values of the perspectives.

Table 4
Self-matrix of criteria under perspective 1.

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22
C1	2.9375	3.0625	2.9688	2.8750	2.9375	2.9688	2.8750	2.7500	3.3750	3.3438	2.9063	2.8125	3.1250	2.7500	3.2813	3.0938	3.0625	3.2500	3.1250	3.2188	2.8125	3.0625
C2	3.2813	3.2188	2.6563	2.5938	3.3125	2.8750	3.0625	3.5000	3.1250	2.4688	3.3125	2.4063	3.1875	3.4375	2.9688	3.0313	2.9063	3.5625	2.4375	3.3125	3.4375	2.8125
C3	3.1250	3.4063	3.1250	2.8125	2.9688	2.9375	3.2500	2.9375	3.0313	3.1563	3.0625	3.1250	2.8438	2.7188	3.1250	3.0000	3.2500	2.6563	2.8750	2.9688	2.8750	3.0000
C4	3.2188	3.1563	2.9063	2.5938	2.9375	2.9375	2.9688	3.2188	3.2188	2.9688	3.0000	3.3125	2.9375	3.1250	2.8438	3.0313	2.6563	2.6563	2.7500	3.0625	3.2188	3.2500
C5	3.0313	3.1250	3.2813	2.9375	3.1250	3.2500	3.0313	2.6875	3.0313	3.2500	2.7813	3.1250	3.0938	3.1250	3.0625	2.8125	2.6875	2.7188	2.7500	3.0625	2.9688	3.1875
C6	2.7188	2.8125	3.2813	3.5625	3.2500	3.2500	3.4375	3.5938	2.7500	3.4688	3.3438	3.4375	2.8750	2.5625	2.8750	2.7188	3.1250	3.0938	2.7500	2.8125	2.8750	3.4688
C7	3.0313	2.6875	3.0000	2.9063	3.3750	2.6875	3.1563	2.9375	3.1875	3.0938	3.1875	2.8750	2.8438	3.2188	3.2188	3.1563	2.9375	2.6250	3.4063	3.0625	2.8438	2.5938
C8	2.9688	2.6875	3.1875	3.0313	3.1563	3.1563	2.6875	3.2188	3.0000	2.9063	2.7188	2.9375	3.1563	2.6875	3.4063	2.9688	2.8438	3.0000	3.6250	2.8125	3.0000	3.0938
C9	3.2188	3.0313	2.8750	3.1875	3.2813	2.7813	2.6563	2.9688	3.1250	2.9375	2.8438	3.2188	3.0625	3.1875	3.2813	3.0938	2.9375	2.8750	3.2188	3.0000	3.3125	3.0625
C10	3.0313	3.3125	3.2500	3.2500	2.9688	3.2500	2.8125	2.8438	2.6875	2.8438	2.5625	2.6563	3.1563	2.9063	2.8438	2.5625	2.9688	2.8438	2.7813	3.5625	2.8750	3.2188
C11	3.7188	3.1250	2.9375	3.0625	2.9063	2.6250	3.0313	2.5625	3.1563	3.2188	3.1875	3.3438	2.5313	3.1563	3.0000	3.1563	3.2500	3.0313	3.6250	3.0313	3.5000	2.5938
C12	3.0938	3.4375	3.2188	2.8438	3.2813	3.1563	2.9688	2.6563	3.1563	2.5000	3.4063	2.9375	2.8438	3.2500	3.1875	2.6250	2.9688	2.8750	3.2500	2.7813	3.0938	3.2188
C13	3.6563	2.9063	3.0625	2.7188	3.1563	3.0938	3.0625	3.0000	3.1875	2.9688	2.7188	3.0313	3.4688	3.2188	3.2188	3.2188	3.2500	2.7188	2.7188	3.2813	2.9063	3.2188
C14	2.8125	3.0625	3.1563	2.9063	3.0313	3.4063	3.3125	2.5938	2.7188	3.1875	3.2188	3.4063	3.1250	3.0625	3.1250	3.0938	2.7813	3.0313	3.5625	3.3125	3.2500	2.9688
C15	3.3438	3.0625	3.2500	2.7500	2.8125	3.0313	2.7813	2.9688	3.2500	2.6563	2.7188	2.7188	3.0625	2.9063	3.0938	2.8125	2.8438	3.1563	2.9063	3.0000	3.0625	3.1875
C16	3.3750	3.4688	3.1563	2.8125	3.0000	2.9063	2.5938	2.8438	3.1563	2.4688	2.9375	3.1250	3.2188	3.1250	3.0000	2.7813	2.7813	3.0000	2.7500	3.5313	2.5313	2.9688
C17	2.5938	2.4688	2.7188	2.6875	2.8125	2.9688	2.9063	3.4688	2.5313	3.0000	3.0000	3.0000	2.9063	3.2500	3.1563	2.4375	3.1250	2.7188	2.6563	3.2813	3.2188	3.0625
C18	3.4375	3.1250	2.6875	3.0313	2.4375	2.9688	3.0938	2.7500	2.9688	2.2500	2.8125	3.2188	2.8125	2.4375	2.6563	2.8750	3.4375	2.9063	2.7188	2.7188	2.8750	3.0625
C19	3.3750	2.6563	2.7188	3.3125	2.9063	3.2188	3.0938	2.7500	3.0625	3.2500	2.7500	2.6563	2.4688	2.9688	3.0625	3.3438	3.1563	3.1563	3.0000	3.3125	2.9375	3.2500
C20	3.4063	3.1250	3.0000	3.1250	3.4063	2.6250	2.7188	3.2500	2.7500	3.0313	3.3125	2.6875	2.7188	3.1250	3.1250	2.6563	2.6875	2.9063	3.2813	3.0000	3.3438	3.4375
C21	3.2500	3.1250	3.0625	2.7188	2.8125	2.3750	2.4688	3.1875	2.9375	2.5000	3.2500	3.1250	3.1875	3.2500	2.6875	3.2500	3.1875	2.8438	3.0000	2.8125	3.2500	2.8750
C22	3.3438	3.2813	3.0313	2.6875	3.0000	3.1875	3.3750	3.4063	2.7188	3.3438	3.0000	3.2188	3.0625	3.0000	3.1250	2.9063	2.6875	3.0313	3.0938	3.3125	2.8750	3.0313

Table 5
Direct relation matrix of all criteria.

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22
C1	3.1771	3.0104	2.9896	3.0000	3.0833	2.9375	2.9479	2.8750	2.8958	3.0521	2.9375	2.9063	3.2708	3.0521	3.0104	3.1354	3.0313	3.0625	3.1146	3.1771	2.8750	2.9479
C2	3.0833	3.1250	2.7396	3.0938	3.1563	2.9271	3.2917	3.2604	3.0104	2.7708	3.0729	2.7083	3.0625	3.0313	3.0625	2.8646	3.0104	3.2708	3.0104	3.2813	3.0104	2.8854
C3	3.2708	3.0417	3.1667	2.8021	3.0313	2.8542	2.8958	2.9375	3.0938	2.7813	2.8854	3.0417	3.0833	2.9375	2.9479	3.0729	3.1146	2.7500	3.1458	3.1042	2.7083	2.9583
C4	3.0938	2.9688	2.8125	3.0313	2.9375	2.9271	3.0417	3.1250	2.9375	2.8542	2.8229	3.2813	3.0417	2.9479	3.0729	2.9271	2.8229	2.8333	2.8854	3.1042	3.1354	3.1667
C5	3.0208	2.8854	3.1563	3.1875	3.0625	3.1458	2.8125	3.0938	3.0521	3.0208	2.6979	3.1771	3.0521	2.9063	3.0104	2.9063	3.1563	2.7917	2.9375	3.1771	2.9375	3.1146
C6	2.9479	2.9792	2.8646	3.2292	3.0938	3.1979	2.9271	3.2604	3.0521	3.0417	3.2396	3.0938	2.8646	2.8021	3.0729	2.9167	3.0104	3.2396	2.8542	3.0417	3.0417	3.2083
C7	3.1667	2.8542	2.7813	2.8229	3.2083	2.9583	3.0833	2.8333	3.0417	2.9271	3.2604	3.0313	2.7500	3.0625	3.1042	3.1146	3.1250	3.0938	3.3854	3.1563	2.9375	2.6979
C8	3.1458	2.9375	3.0833	3.0417	3.0833	2.9583	2.9896	3.2083	3.0208	3.0729	2.9583	2.9479	2.7708	2.9896	3.0104	3.1563	2.8542	3.1354	3.1979	2.7813	2.9583	3.1354
C9	3.0625	2.9792	3.1458	2.8125	3.0938	2.7917	2.9479	3.0521	2.9792	3.0417	2.8646	3.0938	3.0521	3.1875	3.3229	3.2083	2.7813	3.1667	3.1146	3.1875	3.3125	3.1563
C10	2.9375	3.2604	3.1563	3.1667	2.9688	3.3125	2.8438	2.8750	2.8229	2.7083	2.6458	2.9688	3.0000	3.0521	2.8958	2.7604	3.1771	3.0729	2.8125	3.2083	3.0417	3.1563
C11	3.6354	3.0208	2.9375	2.8229	2.7188	2.8333	3.1458	2.8854	2.9896	2.9583	3.2292	3.0104	2.8958	3.0833	3.0208	3.1875	3.2188	2.9375	3.3125	2.8229	3.2188	2.7396
C12	3.2292	3.0313	3.2396	2.9896	2.8854	3.1250	2.7708	2.9063	2.8646	2.6250	3.1875	2.8750	2.8958	3.1146	3.1354	2.7604	3.0208	2.8542	3.3438	2.8021	2.9583	3.2500
C13	3.2083	3.1771	2.9583	2.7500	3.1458	3.0000	3.1146	2.9688	3.1875	3.1250	2.7813	3.2813	3.0625	3.1771	3.2604	3.0521	3.0729	3.1563	2.8542	3.1146	2.8958	2.9583
C14	2.9896	2.9688	3.0729	3.0000	2.8542	3.1875	3.1458	2.9271	2.8542	3.0208	3.1250	3.0625	3.1146	2.8438	2.9896	2.9375	2.5521	2.9896	3.2604	3.1875	2.9688	2.9792
C15	3.1771	3.1458	3.1146	2.8438	2.9271	3.0833	2.8958	2.9167	3.0521	2.6979	2.9271	2.9063	3.0938	2.9583	2.8958	2.8750	3.0833	3.0625	3.0000	2.9375	3.0417	3.0104
C16	3.2083	3.0833	2.9063	2.8438	3.0625	3.0729	2.7708	2.8333	3.0000	2.9583	3.0313	2.9271	3.1250	2.9792	2.8958	2.9792	3.0208	2.9583	2.9896	3.2500	2.9479	3.1667
C17	2.8646	2.7604	2.8229	3.0417	2.8750	3.0104	3.0417	3.0833	3.0521	3.1250	2.9167	2.8438	3.1250	3.1979	2.8542	2.9792	2.9896	2.8021	3.0313	2.9479	3.1563	3.0625
C18	3.0000	2.9792	2.9583	2.8750	2.9167	3.0313	3.1042	3.2500	2.8958	2.6250	3.0208	3.1042	2.8750	2.7500	3.0208	3.1146	3.2083	3.0417	2.8750	2.8125	2.9167	3.3542
C19	2.9271	2.9375	3.1563	3.1563	2.7708	3.0833	3.0521	3.0417	3.1250	3.1146	2.8750	3.0417	2.7708	3.0104	3.1563	3.0313	3.0938	3.0938	2.9479	3.2917	3.0313	3.0833
C20	2.9896	3.1875	2.9479	3.1771	3.1354	2.9688	2.6146	3.1458	2.9792	2.9792	2.9792	2.9688	2.7604	3.0417	3.1146	2.8125	3.0104	3.1979	3.1563	2.8854	3.0000	3.3542
C21	2.8542	2.9167	3.1042	3.0729	2.9479	2.8854	2.8438	2.9792	2.9688	2.8542	3.1458	2.7813	2.8750	3.2188	2.6875	3.1146	3.0000	2.8958	3.1042	2.9375	3.1354	3.0208
C22	3.1979	2.9896	2.9479	3.1042	2.9896	3.0521	3.3021	3.1250	2.8333	3.0417	3.0208	3.0625	2.9063	2.9271	3.0313	2.9271	2.8646	3.0625	2.9271	3.1458	2.8750	2.7813

5. Using Eqs. (15) and (16) can generate the total relation matrix after obtaining these crisp values of the perspectives. Then, the effects diagram of perspectives can be generated using Eq. (17). Eventually, the cause and effect diagram of the criteria can be compared with the effects diagram of the perspectives to confirm the validity of the results.

4. Results

The industrial information and analytical results are reported. The analytical results include the numerical calculations based on the proposed analytical procedures, and they are presented to increase our understanding of the FSE-DEMATEL application.

4.1. Industrial information

International regulations have generated enormous impacts on the industrial sector, and considerable attention was focused on meeting international standards for export requirements from 2006 to 2010. Subsequently, the industrial sector concentrated on cloud computing and expanded this technology so that it could be integrated with other industries, thereby achieving industrial transformations between 2011 and 2015. Recently, unmanned aerial vehicles, virtual reality, augmented reliability and artificial intelligence have undergone rapid growth and drawn interest from the public. In addition, the industrial sector has developed intelligent wearable devices, intelligent clothing, functioning robots and service robots to satisfy the consumer needs and improve medical care. Among these rapid changes and expansions, resources must be balances to improve time management and properly reflect actual conditions.

Thus, SRM was proposed and adopted by the Taiwanese electronics industry. Although the industry realized that balancing resources is an important process, the required practices have not been properly implemented. In particular, resources continue to be wasted when balancing and improving performance; however, the feedback indicates that the practices do not meet expectations. The electronics industry requested the assistance of several consulting agencies to evaluate their performance and provide guidelines; however, these agencies failed to address the problems because inadequate tools were used in the evaluation. This study collected opinions from 55 industrial professionals and academic experts to analyze the SRM. These experts are at the management level or consultants to the industry. These resources might present interrelations with each other, which was also neglected in the past evaluation. Hence, to provide an appropriate evaluation tool that can meet the industrial requirement, the FSM-DEMATEL method is proposed to address the qualitative information, hierarchical structure and interacted relationships among the measures. The analytical results are presented in the following subsection, which indicates the observed limitations for further improvement.

4.2. Analytical results

1. The exploratory factor loading for each criterion ranges between 0.725 and 0.923, and the results satisfy the 0.500 threshold. The internal consistency measured by Cronbach's alpha meets the acceptable level of 0.600.

   Then, the crisp value is attained as follows:

These crisp values are arranged into a direct relation matrix as shown in Table 9.

Table 10 displays the total relation matrix of the perspectives, which is obtained using Eqs. (15) and (16). Eq. (17) calculates the threshold value as $\vartheta = \frac{\sum_{o=1}^{\beta} \tilde{s}_{ol}}{\beta^2} = \frac{(30.7953+31.1039+30.6664+30.7147+31.0206+30.5908+29.8621+30.1733+29.7431)}{3^2} = 30.5189$. Thus, the effects between A1 and A2 are identified, which yields a value of $31.1039 > \vartheta$ and shows that A1 interacted with A2. Thus, according to these identifications, these effects can be used to generate an effects diagram of perspective as shown in Fig. 2. This diagram shows that A1 and A2 interact with each other and greater effects occur between them; then, A3 is affected by A1 and A2. Finally, a comparison of Figs. 1 and 2 demonstrates the validity of this study. C2, C6, C9 and C13 belong to A1 and A2 separately, and these values are all grouped among the cause attributes and impact C19, C20 and C22 in terms of A3.

Table 6
Total relation matrix of the criteria.

3. We adopted $(dr + dp)$ as the horizontal axis and $(dr - dp)$ as the vertical axis to map the criteria for the cause and effect diagrams as shown in Fig. 1. These four quadrants offer a clear visual analysis for making decisions. Within this diagram, C2, C6, C9 and C13 are located in quadrant I, and they are considered the driving attributes; C5, C7, C10, C11 and C16 fall into quadrant II, and they are considered the voluntary attributes; C3, C4, C12, C14, C15, C17, C18, and C21 fall into in quadrant III, and they are considered the independent attributes; and C1, C8, C19, C20, and C22 are in quadrant IV, and they are considered the core problems.

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	*dr*
C1	2.8047	2.7234	2.7161	2.7087	2.7129	2.7266	2.6962	2.7359	2.7004	2.6501	2.6979	2.7168	2.6955	2.7252	2.7372	2.7092	2.7228	2.7339	2.7666	2.7711	2.7158	2.7611	59.9281
C2	2.8134	2.7349	2.7221	2.7198	2.7237	2.7362	2.7110	2.7515	2.7118	2.6555	2.7097	2.7236	2.7020	2.7347	2.7478	2.7149	2.7323	2.7469	2.7750	2.7825	2.7276	2.7701	60.1466
C3	2.7705	2.6893	2.6842	2.6713	2.6777	2.6906	2.6611	2.7020	2.6690	2.6125	2.6628	2.6842	2.6585	2.6889	2.7015	2.6738	2.6895	2.6946	2.7319	2.7348	2.6787	2.7261	59.1537
C4	2.7735	2.6937	2.6844	2.6802	2.6817	2.6972	2.6687	2.7103	2.6721	2.6188	2.6674	2.6932	2.6632	2.6946	2.7088	2.6771	2.6906	2.7013	2.7336	2.7403	2.6906	2.7348	59.2761
C5	2.7944	2.7138	2.7108	2.7038	2.7049	2.7219	2.6864	2.7313	2.6950	2.6421	2.6866	2.7130	2.6845	2.7153	2.7293	2.6980	2.7169	2.7221	2.7560	2.7631	2.7089	2.7557	59.7538
C6	2.8214	2.7424	2.7337	2.7315	2.7324	2.7499	2.7152	2.7612	2.7220	2.6689	2.7217	2.7390	2.7086	2.7410	2.7577	2.7253	2.7420	2.7561	2.7825	2.7888	2.7377	2.7848	60.3638
C7	2.8006	2.7172	2.7092	2.7022	2.7109	2.7230	2.6944	2.7314	2.6988	2.6445	2.6990	2.7148	2.6839	2.7216	2.7347	2.7051	2.7204	2.7305	2.7667	2.7668	2.7129	2.7535	59.8421
C8	2.8018	2.7199	2.7151	2.7069	2.7105	2.7245	2.6945	2.7384	2.6999	2.6481	2.6959	2.7150	2.6857	2.7219	2.7348	2.7071	2.7178	2.7326	2.7654	2.7628	2.7146	2.7615	59.8748
C9	2.8383	2.7573	2.7527	2.7400	2.7472	2.7587	2.7301	2.7730	2.7356	2.6833	2.7308	2.7537	2.7261	2.7616	2.7762	2.7443	2.7534	2.7699	2.8014	2.8061	2.7565	2.7990	60.6953
C10	2.7740	2.7008	2.6923	2.6850	2.6850	2.7058	2.6686	2.7095	2.6732	2.6194	2.6676	2.6914	2.6654	2.6989	2.7090	2.6774	2.6986	2.7077	2.7353	2.7447	2.6920	2.7375	59.3392
C11	2.8170	2.7288	2.7206	2.7113	2.7127	2.7302	2.7044	2.7413	2.7070	2.6539	2.7075	2.7235	2.6951	2.7310	2.7426	2.7152	2.7309	2.7373	2.7749	2.7711	2.7262	2.7633	60.0457
C12	2.7796	2.6985	2.6946	2.6834	2.6848	2.7040	2.6686	2.7110	2.6749	2.6193	2.6767	2.6911	2.6649	2.7009	2.7136	2.6785	2.6974	2.7055	2.7444	2.7398	2.6918	2.7399	59.3633
C13	2.8388	2.7585	2.7482	2.7374	2.7463	2.7602	2.7309	2.7701	2.7371	2.6829	2.7279	2.7548	2.7246	2.7597	2.7737	2.7403	2.7560	2.7681	2.7959	2.8033	2.7486	2.7944	60.6575
C14	2.7832	2.7046	2.6991	2.6905	2.6913	2.7120	2.6810	2.7183	2.6817	2.6319	2.6827	2.7009	2.6750	2.7039	2.7185	2.6881	2.6975	2.7146	2.7502	2.7526	2.6989	2.7431	59.5197
C15	2.7698	2.6915	2.6841	2.6726	2.6768	2.6947	2.6619	2.7024	2.6691	2.6119	2.6642	2.6829	2.6593	2.6899	2.7014	2.6716	2.6897	2.6999	2.7305	2.7330	2.6844	2.7276	59.1695
C16	2.7855	2.7054	2.6958	2.6874	2.6936	2.7094	2.6746	2.7161	2.6830	2.6302	2.6804	2.6980	2.6744	2.7050	2.7162	2.6878	2.7035	2.7132	2.7453	2.7527	2.6978	2.7450	59.5001
C17	2.7624	2.6831	2.6772	2.6729	2.6734	2.6910	2.6614	2.7022	2.6664	2.6157	2.6614	2.6793	2.6571	2.6908	2.6981	2.6705	2.6856	2.6934	2.7282	2.7305	2.6835	2.7257	59.1099
C18	2.7704	2.6920	2.6848	2.6761	2.6797	2.6970	2.6680	2.7104	2.6697	2.6138	2.6686	2.6888	2.6590	2.6899	2.7063	2.6782	2.6946	2.7026	2.7317	2.7342	2.6856	2.7358	59.2369
C19	2.8130	2.7340	2.7302	2.7226	2.7199	2.7404	2.7093	2.7501	2.7153	2.6624	2.7086	2.7304	2.6995	2.7363	2.7510	2.7192	2.7354	2.7461	2.7760	2.7846	2.7297	2.7750	60.1889
C20	2.7981	2.7223	2.7118	2.7076	2.7099	2.7233	2.6876	2.7362	2.6979	2.6454	2.6948	2.7139	2.6842	2.7213	2.7349	2.7006	2.7187	2.7322	2.7634	2.7629	2.7139	2.7634	59.8443
C21	2.7522	2.6756	2.6715	2.6636	2.6646	2.6793	2.6487	2.6908	2.6554	2.6021	2.6551	2.6686	2.6437	2.6813	2.6857	2.6628	2.6759	2.6848	2.7193	2.7203	2.6733	2.7151	58.8897
C22	2.7894	2.7079	2.7003	2.6951	2.6963	2.7130	2.6863	2.7243	2.6843	2.6351	2.6841	2.7038	2.6749	2.7081	2.7222	2.6909	2.7051	2.7186	2.7484	2.7550	2.7006	2.7432	59.5869
	61.4520	59.6949	59.5387	59.3701	59.4363	59.7888	59.1089	60.0176	59.2196	58.0476	59.1514	59.5807	58.9850	59.7218	60.0011	59.3361	59.6747	59.9119	60.6225	60.7009	59.5696	60.5557	

Table 7
Factor weights for the perspectives.

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
A1	3.0216	3.0203	3.0063	2.9916	2.9999	3.0773	2.9929	3.0028	3.0475	2.9521	3.0638
Factor weight	0.1431	0.1431	0.1424	0.1417	0.1421	0.1458	0.1418	0.1413	0.1434	0.1389	0.1442
A2	3.0127	3.0099	2.9109	2.9806	2.9663	3.0523	3.0557	3.0700	3.0039	3.0518	2.9252
Factor weight	0.1435	0.1434	0.1387	0.1420	0.1413	0.1454	0.1456	0.1458	0.1427	0.1449	0.1389
A3	3.0133	3.0281	2.9988	2.9710	3.0499	2.9705	2.9736	2.9567	3.1051	2.9447	3.0598
Factor weight	0.1435	0.1442	0.1428	0.1414	0.1452	0.1414	0.1416	0.1411	0.1482	0.1406	0.1461

	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22
A1	3.0236	3.0718	3.0877	2.9654	2.9660	2.8945	2.8615	3.0074	3.0205	2.9485	3.0706
Factor weight	0.1423	0.1446	0.1453	0.1249	0.1250	0.1220	0.1206	0.1267	0.1273	0.1242	0.1294
A2	2.9391	3.0529	3.0140	3.0276	2.9695	2.9586	3.0494	3.0925	3.0281	2.9229	2.9768
Factor weight	0.1396	0.1450	0.1431	0.1260	0.1236	0.1231	0.1269	0.1287	0.1260	0.1217	0.1239
A3	2.9832	3.0252	2.8741	2.9376	3.0361	3.0599	3.0169	2.9815	2.9724	2.9977	2.9381
Factor weight	0.1424	0.1444	0.1372	0.1227	0.1268	0.1278	0.1260	0.1245	0.1242	0.1252	0.1227

5. Eqs. (12) and (13) are used to attain the membership function and crisp value of the perspectives as shown in Table 8. Based on these equations, the membership function of A1 is calculated as follows:

$$[F]^{\beta}_{pq} \times [\tilde{\varepsilon}]^{\beta}_{qr} = [0.1431 \quad 0.1431 \quad 0.1424 \quad 0.1417 \quad 0.1421 \quad 0.1458 \quad 0.1418] \times \begin{bmatrix} 0.1825 & 0.1883 & 0.1868 & 0.1943 & 0.1974 \\ 0.1825 & 0.1536 & 0.2050 & 0.1854 & 0.1952 \\ 0.1857 & 0.2055 & 0.1803 & 0.1657 & 0.2057 \\ 0.1852 & 0.1878 & 0.1928 & 0.1833 & 0.1882 \\ 0.1973 & 0.1662 & 0.1836 & 0.2105 & 0.1878 \\ 0.1551 & 0.1887 & 0.1818 & 0.1908 & 0.2002 \\ 0.1809 & 0.2000 & 0.1858 & 0.1960 & 0.1876 \end{bmatrix} = [0.1812 \quad 0.1843 \quad 0.1880 \quad 0.1894 \quad 0.1946]$$

Table 8
Membership function and crisp value under A1.

	A1					
	Membership Function					Crisp Value
A1	0.1812	0.1843	0.1880	0.1894	0.1946	2.8446
A2	0.1734	0.1826	0.1918	0.1824	0.1973	2.8300
A3	0.1946	0.1809	0.1896	0.1602	0.1885	2.7084

Table 9
Direct relation matrix of the perspectives.

	A1	A2	A3
A1	2.8446	2.8453	2.8026
A2	2.8300	2.8139	2.8275
A3	2.7084	2.8096	2.7189

Table 10
Total relation matrix of the perspectives.

	A1	A2	A3
A1	30.7953	31.1039	30.6664
A2	30.7147	31.0206	30.5908
A3	29.8621	30.1733	29.7431

5. Implications

This section discusses the effects of reinforcing the theoretical and managerial implications associated with providing a guideline for industry improvements represented by a perspective map and criterion weight prioritization.

5.1. Theoretical implications

Social and environmental resources have driving features that affect economic resources. In other words, economic resources are acquired by promoting the improvement of social and environmental resources. Social resources interact with environmental resources and generate moderate effects on economic resources. This result offers solid evidence supporting the arguments that SRM must consider social resources (Pahl-Wostl, 2007; Pahl-Wostl et al., 2013). Social resources enable the generation of unexpected feedback that can assist industry in attaining sustainability. The results also indicate that social resources can impact the acquisition of environmental and economic resources by increasing human capital development and synergistic organization. Human capital development enables can facilitate resource acquisition by offering education, training, welfare and healthcare, whereas synergistic organization facilitates resource acquisition by promoting shared values among stakeholders via alignments with the target. This analytical result emphasizes the priority of social resources in SRM, and it reveals that if social resources do not focus on balancing resource acquisition, then the environmental and economic resources might present an inadequate and inefficient performance.

Environmental resources and social resources interact and affect each other, and they have weak effects on economic resources (Lee et al., 2018; Shi et al., 2017). In general, economic resources are used to obtain environmental resources; however, this assumption is not correct within this study. Because environmental resources are the driving factor affecting economic resources, the Taiwanese electronics industry generates profits by launching eco-innovation and environmental management systems. Eco-innovation enables the gathering of resources through a broader range of innovation,

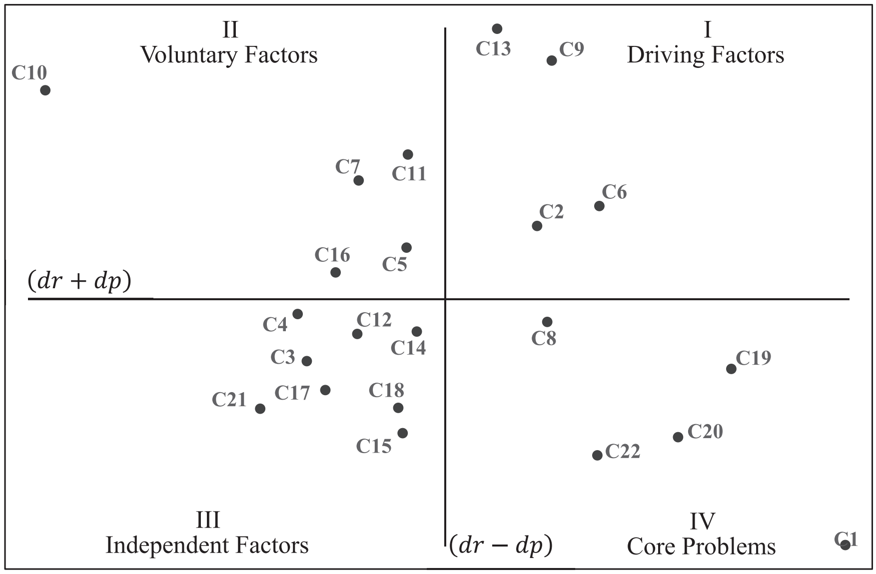

Fig. 1. Cause and effect diagram of the criteria.

4. Table 7 expresses the factor weights for each perspective obtained using Eqs. (10) and (11). Thus, the factor weight of C1 under A1 is calculated as $\frac{m_i}{\sum_{i=1}^{q} m_i} = \frac{3.0216}{(3.0216+3.0203+3.0063+2.9916+2.9999+3.0773+2.9929)} = \frac{3.0216}{21.1099} = 0.1431$.

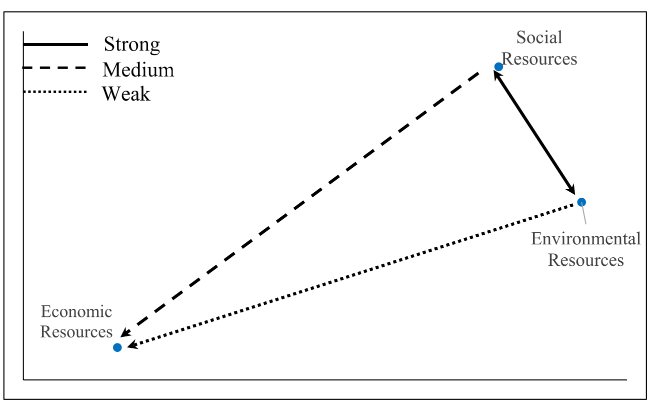

Fig. 2. Effects diagram of the perspectives.

including renewable energy, pollution prevention systems, waste management infrastructures and substitute material adoption (Kemp, 2010; Wu et al., 2016a). In addition, attaining SRM relies on balancing resources, and the environmental management system offers an industry control point for monitoring the performance of environmental resources. The decision-maker can use these drivers to generate economic resources for attaining sustainability.

However, the results revealed that the core problems were caused by supply chain financing, forecasting accuracy and in supply chain network collaboration and coordination. Although these problems prevent economic resources from reaching accepted performance levels, improvement must be made by increasing the performance of social and environmental resources. The Taiwanese electronic industry must prioritize social and environmental resources, which will generate effects on economic resources. The interrelationships among these three types of resource are often neglected in evaluations, thus leading to insufficient results that cannot accurately reflect the real situation. The results presented here offer significant evidence that the proposed hybrid method can promote our understanding of SRM.

5.2. Managerial implications

Specifically, the criteria associated with the driving attributes can be ranked as follows: (1) environmental management system; (2) eco-innovation; (3) synergistic organization; and (4) human capital development. These four criteria exert considerable influence and affect other criteria, and they can provide guidelines for firms for improving the performance of SRM.

The industry launched an environmental management system based on the standard ISO 14001, which references multi-stakeholder perspectives to generate the common requirements for preventing resource waste and improving the efficiency of resource utilization. This system implements the following processes: (1) checking relevant environmental regulations; (2) planning environmental strategies; (3) launching operations; (4) checking and correcting activities; (5) reviewing improvements; and (6) continuing improvements associated with the Plan-Do-Check-Act cycle to attain SRM and a circular economy. Several firms have individually implemented the ISO9001 and OHSAS1800 standards in their current environmental management systems to comprehensively consider the above aspects.

The industry has adopted eco-innovation to balance ecological and economic performance with one-stop service (Wu et al., 2016a). Eco-innovation involves several implementations, which include eco-purchasing, eco-organization, eco-production and eco-design. Most electronics firms are striving to apply all four of these implementations toward SRM; however, the required investments are a major constraint. Co-organization requires the education of employees to improve their environmental consciousness in all activities. Several famous Taiwanese firms have presented their eco-organization performance on their web sites to enhance their reputation and reinforce their social resources for benchmarking practices. These activities are synergetic for firms and provide them with an opportunity to explore internal and external collaborations to attain common values when acquiring resources. The synergetic effects generated by sharing information and rendering information transparent are among the current practices of electronics firms. In particular, the economic, environmental and social

performance must be determined to promote synergy with their multi-stakeholders. This action increases the confidence of stakeholders in their investments, and it also increases the loyalty of employees, thereby generating unexpected social resources for firms attaining SRM.

Human capital development is focused on training and educating employees, and an underlying principle is to put the right person in the right position to maximize functioning. The Taiwanese electronics industry must use its employees as assets; otherwise, the firms will become fossilized, their efficiency will decrease, and their ability to acquire resources will be lost. In current practices, human capital development must have the flexibility to encourage employees to participate in any of the firms' activities. For example, several electronics firms have allocated different consumption levels to all departments based on their annual revenues; if the department can reduce their consumption to reach a certain level, then these reductions will be transformed into an annual bonus for each employee in this department. Thus, human capital development must focus on methods of motivating employees to perform their functions well.

The following five criteria represent the core problems with the worst rankings: (1) multi-stakeholder engagement; (2) collaboration and coordination in supply chain networks; (3) forecasting accuracy; (4) supply chain finance; and (5) employee and customer awareness. SRM performance cannot be promoted by ameliorating these five problems directly; instead, it must rely on the linking effects associated with the driving attributes because of the observed interrelationships. These five problems arise because industries have been focused on arranging their own resources. Thus, the results provide significant evidence that these interrelationships must be considered to reflect the problem in reality, especially because these interrelationships were omitted in prior studies. In addition, these interrelationships can also be considered guidelines to improve the performance of SRM.

6. Conclusions

SRM should be properly considered to address the recent issues of resource exhaustion and climate change. However, relevant studies have primarily focused on environmental and economic resources and neglected social resources. The Taiwanese electronics industry has an urgent need to develop an appropriate tool that considers the interrelationships and multi-dimensions associated with SRM. Hence, this study selects 22 criteria for SRM practices and uses them to generate 3 perspectives via an exploratory factor analysis. The proposed evaluation method combines the FSE and DEMATEL to identify the possible drivers and problems, which are used as guidelines for performance improvements. This hybrid method enables the complex problems to be simplified via a visual analysis and overcomes the shortcomings of prior studies by forming a hierarchical analytical structure and performing analyses of the interrelationships among the attributes based on linguistic preferences.

This study fills the gaps observed in prior studies with a reliable and valid analysis. Hence, this study (1) provides significant evidence to reinforce our understanding of SRM; (2) categorizes the criteria and perspectives used to generate the cause and effect diagrams by adopting a visual analysis and considering the hierarchical structure; and (3) identifies effective drivers and core problems as guidelines to assist the Taiwanese electronics industry in improving performance. The implications confirmed that social resources must prioritize SRM because social resources enable the generation of unexpected feedback to enhance the sustainability performance. Moreover, social and environment resources interact and are among the causal attributes. Consequently, economic resources are affected by social and environment resources as well.

The analytical results presented for the proposed perspectives and criteria can accurately reflect the situation of the Taiwanese electronics industry, and the evaluations provide accurate and reliable results for improving a firm's ability to achieve SRM. The results indicate that performance declines with the use of economic resources that present poor performance, such as supply chain finance, forecasting accuracy and collaboration and coordination in supply chain networks. However, the performance of these criteria cannot directly ameliorate the associated issues, which can be achieved only by promoting environmental management system performance, eco-innovation, synergistic organizations and human capital development. Specifically, environmental management systems have the greatest influence on the other criteria.

This study also had certain limitations. First, although the study comprehensively reviewed the literature to select the proper criteria to reflect the actual conditions, the study might not have covered all considerations. Thus, future studies should consider as many additional criteria as possible to perform a more thorough analysis and ensure that the results can properly address real problems. Second, experts were selected from related Taiwanese electronics industries; therefore, the evaluation results might present opinions that are too narrow and lack external generalizability. Future studies could choose experts from other countries or industries to overcome this limitation. Third, SRM includes diversity measures for evaluations based on experts' knowledge and experiences and thus could reflect subjective preferences. To overcome this shortcoming, qualitative information and quantitative data should be integrated to effectively eliminate subjective preferences.

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